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REVIEW

Can very early music interventions promote at-risk infants' development?

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Music and musical activities are often a natural part of parenting. As accumulating evidence shows, music can promote auditory and language development in infancy and early childhood. It may even help to support auditory and language skills in infants whose development is compromised by heritable conditions, like the reading deficit dyslexia, or by environmental factors, such as premature birth. For example, infants born to dyslexic parents can have atypical brain responses to speech sounds and subsequent challenges in language development. Children born very preterm, in turn, have an increased likelihood of sensory, cognitive, and motor deficits. To ameliorate these deficits, we have developed early interventions focusing on music. Preliminary results of our ongoing longitudinal studies suggest that music making and parental singing promote infants' early language development and auditory neural processing. Together with previous findings in the field, the present studies highlight the role of active, social music making in supporting auditory and language development in at-risk children and infants. Once completed, the studies will illuminate both risk and protective factors in development and offer a comprehensive model of understanding the promises of music activities in promoting positive developmental outcomes during the first years of life.

Keywords: music interventions; infancy; EEG/MEG; dyslexia; prematurity

Introduction

Music is nearly all-encompassing in early development. The interaction between infants and caregivers is often musical, involving play songs and lullabies, as well as rhythmic movements, such as clapping hands to a nursery rhyme or bouncing or rocking children in time with music. We even talk to children in parentese, which is rich in musical features, such as exaggerated pitch changes.[1] These musical phenomena have an important role in human development. For example, the exaggerated cues in parentese aid infants in their discrimination of words.[2] Also, infant-directed singing and caregiver-mediated musical play capture the infants' attention and help them to modulate their arousal and synchronize with their caregivers,[3] promoting parental sensitivity. This positively correlates with attachment security, resulting in beneficial socioemotional outcomes.[4]

Musical play is prevalent in interaction between parents and young children, as it can be motivating and engaging. Music activities are also associated with improved auditory, linguistic, and literacy skills in children and adults.[5–7] Thus, early music interventions and musical activities at home could potentially support development in both healthy infants and those at risk of adverse outcomes. Owing to their playful and nonverbal nature, musical interventions may even help children who are too young for most rehabilitative interventions. For example, language development could already be supported during the critical period in infancy, when the neural representations for native language phonemes are formed.[8]

Caregiver involvement might be effective in very early music interventions, particularly in the case of at-risk children, whose parents would benefit from easy and concrete tools to support the child's

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development. For example, developmental dyslexia, a reading deficit associated with language impairments and auditory processing deficits, is heritable, and therefore often evident in both parent and child.[9–11] A dyslexic parent knows the challenges of growing up with a learning disorder, but, because of the disorder, his/her own resources for facilitating the child's language development may be limited. On the other hand, with infants born very preterm, the parents often suffer from anxiety and are naturally highly concerned for their child's welfare.[12] An intervention that allows the caregivers to take an active role in helping their child in the hospital may reduce parental anxiety and worry for the future of their child.

Here, we discuss the possibilities for very early music interventions and caregiver–child music activities in promoting at-risk infants' neurocognitive development. A very early intervention is defined here as one targeted at the first months of life, aiming for positive developmental outcomes that are possibly only seen years later (e.g., when the children start producing speech or practice reading at school). In our ongoing projects, we assess the extent to which hearing recorded music or parental singing in infancy, as well as informal music activities at home during first years of life, could be beneficial for auditory and language development. Before presenting the preliminary results of our studies, we review findings on the possible effects of music in supporting auditory and language development in healthy infants and children. Then, we move on to at-risk children, with a focus on two conditions: familial risk for developmental dyslexia and premature birth. We present research on the promises of music in preventing or ameliorating negative outcomes in these children, together with preliminary results from two ongoing large-scale longitudinal studies. The studies investigate the role of an early music intervention and informal music activities at home in supporting auditory and language development in early childhood.

Promises of music for auditory and language development in infants and children

Music making seems to have an effect on language and literacy skills in children and adults, likely mediated via benefits for (rapid temporal) auditory processing.[5–7] For example, music training is associated with enhanced neural speech processing (e.g., pitch changes in speech sounds,[13] syllable duration and voice onset time,[14] speech in noise[15]) as well as with good reading-related skills (e.g., verbal memory skills[16,17] and reading comprehension[18]). In two separate intervention studies, school-aged children were randomized to music or painting training, and beneficial effects on reading skills and neural speech sound processing were seen after music training only.[19,20] These studies with randomized groups and pre- and post-testing suggest that the effects of music training are at least to some extent causal rather than correlational.

Already in infancy, an active music-making class, compared with hearing recorded music in the background during a social play class, increased the amount of preverbal communicative gestures as reported by parents in 12-month-olds,[21] as well as auditory cortical processing.[22] Again, randomization to groups and pre- and post-testing strengthen the results, although it is notable that the music-making class may have introduced a more structured setting with more organized group activities than the social play class. In a very recent study, 9-month-old infants were randomly assigned to either a social music intervention focusing on the triple meter (waltz) or a social play intervention without music.[23] The music intervention was associated with improved temporal processing of speech, as evidenced by enhanced auditory event-related potentials (ERPs) in the music group compared with the social play group. However, the results may reflect pre-existing group differences instead of intervention effects, as the study lacks a baseline measurement.

These pioneering results in infants suggest that music may even serve as a preverbal intervention for language, but the studies by Trainor *et al.*[22] and Gerry *et al.*[21] propose that influencing children's development may require active, social engagement with the music instead of, for example, hearing recorded music. Support for this hypothesis is provided by a language learning study by Kuhl and colleagues.[24] Exposure to a foreign language in infancy stopped the age-related decline in the infants' ability to discriminate between foreign language speech sounds, but only when the foreign language was heard in a live, social setting, and not when it was heard from a recording.[24] Another infant intervention compared the effects

of passive sound exposure and an interactive auditory learning setting in 4- to 7-month-olds.[25] Both interventions, but particularly the interactive auditory learning setting, demonstrated benefits for auditory processing (see also, Ref. 26). However, interpreting this finding in the context of language development should be done with caution: the presented stimuli, as well as the outcome measures, were nonlinguistic (although they were considered relevant for language). Nevertheless, the results support the idea that auditory learning in infancy, both in the domains of language and music, may require active participation and social interaction.[27] Although not directly comparable, studies in adults also suggest that active participation and engagement with music (i.e., producing music) has a greater effect on the brains' neural responses than music listening.[28] In this study, music making and listening interventions did not markedly differ in terms of the amount of social interaction, which was minimal in both interventions, according to the authors' description.[28]

When interpreting the previous findings, it is notable that the concepts of "active" and "passive" are defined differently among studies. For example, active music making or an active music intervention can be defined as something that engages the individual's attention with music making, most often in the context of social interaction. Even though this kind of active engagement with music making may be optimal for supporting auditory and language development during childhood, interventions based on music listening can also have an effect on auditory processing or even beyond it. For example, auditory cortical processing in infants has been shown to change as a result of music exposure.[29,30] Hearing either guitar or marimba melodies during one week resulted in selectively enhanced auditory ERPs to guitar or marimba tones and pitch changes in the tones in 4-month-old infants.[29] Exposure to a melody (piano version of "Twinkle, twinkle, little star") even before birth resulted in enlarged ERPs to the melody and changes in it after birth.[30] Although these studies examine a rather passive form of music listening, it is notable that even music listening can engage attention and be socially interactive. Social interaction with music can be facilitated by, for example, directing an infant's attention toward music with activities such as play songs or rocking. In adult poststroke patients, a music-listening intervention was more efficient than audiobook listening in improving verbal memory and focused attention.[31] Both music and audiobook listening improved auditory cortical processing compared with standard care only.[32] It is likely that most of the patients were listening to the music or audiobooks in a rather active manner, consciously processing the auditory information (instead of paying their attention to something else), as this provided them with a meaningful activity during their recovery. Interventions based on music listening may thus be effective for auditory processing and cognition and allow participants to also benefit from music in situations where more active engagement with music proves challenging or impossible. This is the case with very small infants or immobile or hospitalized patients.

Not only formal music training and interventions, but also more informal music activities at home and in musical playschool settings have been shown to be associated with enhanced auditory neural development[33–35] and, to a small extent, with improved neurocognitive and prosocial skills[36] in early childhood. Particularly in the case of small children, activities at home potentially have more widespread effects on their well-being and development than, for example, a weekly piano lesson: musical activities at home can be more frequent and integrated with everyday activities. They may support parent–child attachment and can occur by the child's own volition, making them very motivating for the child. Furthermore, if the home environment supports the child's musical activities, it likely increases an interest even to formal instrument lessons, thus influencing how profound the effects of music are in a child's life. Therefore, neuroscientific studies of music should take at-home informal musical activities into account in addition to formal music lessons or interventions.

A prominent example of musical activities at home is parental singing, a little-studied form of music that has a special role in parent–infant interaction. Infants are attracted to infant-directed singing,[3] and infant-directed speech has singing-like features[1] helping young infants to detect word boundaries.[2] Singing to or with a child may facilitate language learning, as it familiarizes the child with native language speech sounds in an attention-catching and repetitive way. Studies on deaf-born children with cochlear implants suggest that singing

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may be beneficial for neural auditory processing and language skills,[37] while music activities in general may promote prosody perception in speech.[38]

Here, we emphasize the role of music in facilitating early development. Still, it is relevant to note that beneficial effects of musical activities are not always found. For example, in a study of normally developing children, no effects of brief music classes were found on vocabulary, numerical discrimination, or visual skills.[39] As an explanation for this, Schellenberg has proposed that at least some effects of music can be attributed to pre-existing dispositions to music instead of practice effects.[40] However, it also important to separate studies investigating the benefits of music on normally developing children and adults from studies focusing on musical interventions targeted at ameliorating neurocognitive deficits. For typically developing children, the effects of music may be at best "small but general and long lasting."[41] This does not mean that the effects of specifically targeted musical interventions on at-risk children could not be more beneficial.

Very early music interventions in at-risk infants: two examples

Infant brain development can be compromised by heritable conditions, such as familial risk for developmental dyslexia,[42–48] or by environmental factors, such as premature birth.[49–54] Recent findings show promise that music may specifically help to ameliorate developmental dyslexia[55,56] (see also, Refs. 19 and 20) and promote development in preterm infants.[57] Two ongoing large-scale longitudinal research projects in Finland and Sweden aim to shed light on auditory and language development in these two risk groups starting from birth. Music interventions consisting of either recorded music played to the infant or parental singing to the infant supported by a music therapist (details below) are administered during the first months of the infants' life, and auditory and language development as well as music-related activities are carefully followed during childhood. It is relevant to note that the projects did not attempt to replace any standard care practices. In contrast, the aim of the projects was to incorporate music into daily activities starting from infancy, in order to study associations between music and development throughout infancy and early childhood. As such, neither intervention includes an active control group where daily activities would be enhanced by stimulation of a different type or modality. The projects and their preliminary results are presented below.

Dyslexia, infancy, and auditory processing

A widely supported current view on the underlying cause of developmental dyslexia is a phonological processing deficit, a problem in representation and processing of speech sounds characterized by difficulties in, for example, phonological awareness, word finding, and verbal short-term memory.[9,42,43] This view is supported by structural and functional brain evidence from dyslexic individuals showing abnormalities in the left perisylvian cortex, important for phonological processing,[42] as well as auditory neural processing deficits, at least in a subgroup of dyslexics.[10,11] Interestingly, these deficits are demonstrated in children at familial risk for dyslexia, before formal reading instruction,[44] and even in infancy.[45,46] Recent findings in infants at risk of language impairment suggest that auditory brain responses in infancy can also predict later language skills, and thus they may have relevance as neural markers of early language development.[46–48] Early detection of children at highest risk for adverse outcomes using these neural markers has the potential to allow for effectively targeting preventive measures for infants or young children, potentially revolutionizing the rehabilitation of dyslexia and other neurodevelopmental disorders.

Interventions targeted at phonological or auditory processing of dyslexic children have demonstrated improvements in both reading skills and auditory brain responses.[58,59] This suggests that supporting the development of the auditory system could ameliorate or prevent reading problems in childhood. Recent music-based intervention studies on dyslexic children have been associated with benefits in perceiving and producing speech, auditory attention, verbal short-term memory, phonological processing, and reading.[6,55,56,60] A recent study delivered a multimodal musical intervention to dyslexic children and saw various improvements in auditory and reading-related skills; however, there was no comparison to a control group with a different intervention or no intervention, compromising interpretation of the results as intervention effects.[56] A randomized controlled trial found beneficial effects of music over painting training on reading-related skills, with the music intervention

focusing particularly on rhythm and temporal processing[55] (similar focus in classroom music lessons was associated with improved phonological and spelling skills but not reading in another study[6,60]). These promising results raise the question of whether music activities could act as preventive interventions for language and reading difficulties as early as in infancy, when phonological, language, and reading skills cannot yet be targeted directly. Indeed, designing interventions suitable for infants is challenging, as infants are nonverbal, have limited motor control, and lack attentional resources essential for many interventions. The best interventions in infancy are likely to take place in the infant's natural learning environment: at home and/or in interaction with the primary caretakers.

The DyslexiaBaby study

In the DyslexiaBaby study, infants at familial risk for dyslexia are followed from birth onward, and a music listening intervention is administered between birth and 6 months of age. At-risk infants are pseudo-randomized to three groups: music-listening intervention with vocal (sung) material, music-listening intervention with instrumental material, and a no-intervention control group. An additional control group with no dyslexia among close relatives is also included in the follow-up. The material in both interventions consists of Finnish children's and folk songs recorded by the researchers, chosen so that the families would have a wide variety of both peaceful and energetic music to choose from. The melody is either sung by a male or female voice or played with banjo, mandolin, or marimba with silent guitar accompaniment in the background in both vocal and instrumental versions. Parents administer the intervention at home by playing their infants music provided by the researchers on several days per week and reporting the infant's activities when the music was playing (e.g., asleep, awake alone, or socializing with caretaker; see Fig. 1). Vocal music including the language component and resembling parentese is hypothesized to be more effective in promoting the infant's language development than instrumental music. Auditory ERPs to native language speech sound changes are recorded with electroencephalography (EEG) from the infants at birth and again at 6 months. At 2.5 years, the ERP study is repeated, and a comprehensive neuropsychological evaluation of language and cognitive development (including, e.g., the Reynell Developmental Language Scales III[61]) is conducted. Additionally, parents fill in broad questionnaires on early precommunicative development (Finnish version of the Communication and Symbolic Behavior Scales, Developmental Profile, CSBS DP[62]) and family environment and background (e.g., socioeconomic status), especially regarding how much the infants hear music and languages and how often they engage in music- and language-related activities at home (a customized questionnaire designed in the project). Plenty of additional information on factors including home literacy is collected throughout childhood in order to take into account differences between families and find the best predictors of children's auditory and language development.

Preliminary results from the DyslexiaBaby study at the 6-month follow-up demonstrated very modest or nonexistent effects of the music listening interventions on auditory ERPs or precommunicative development when approximately half of the data

Figure 1. **Music listening intervention in the DyslexiaBaby study.**

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were preliminarily analyzed (at-risk infants $n = 78$, final sample $n = 150$). Consistent with previous findings with typically developing older infants,[21,22] this suggests that passive exposure to music may not be enough to support auditory and language development in infancy. However, correlations were seen in the preliminary analysis between the latencies and amplitudes of the auditory ERPs and precommunicative development scores in 6-month-old infants at familial risk for dyslexia, when socioeconomic status and child gender were controlled for. Infant ERPs may thus serve as an early neural marker for language abilities and deficits, in line with previous findings.[46–48]

Remarkably, in the preliminary results of the DyslexiaBaby data, both auditory ERPs and precommunicative development scores showed correlations with several music and language-related activities as reported by the parents in questionnaires at 6 months of age, with socioeconomic status and group status (intervention or no intervention) controlled for in the analyses. Particularly, the amount of informal musical activities at home (dancing or moving to music, drumming or tapping rhythms, and playing musical instruments) and singing at home were positively linked to precommunicative development scores, and participation in musical play school and reading aloud at home were positively linked to maturity of the auditory ERPs (e.g., larger amplitudes and shorter latencies of several components). Besides the results by Putkinen *et al.*[33,34] who demonstrated positive effects of musical activities at home on auditory neural processing in toddlers, we are aware of no similar findings in infants this young.

Prematurity and its risks

Although a majority of infants who are born very preterm (before 32 weeks gestational age) develop normally, very preterm children have increased risk of cognitive deficits.[49] These deficits are often characterized by difficulties in reading, learning, language, and memory; however, they may also include difficulties in attention, behavioral problems, poor executive functions, and visuospatial deficits.[49] Thus, premature birth and small birth weight may particularly predispose the preterm infant to low academic achievement (e.g., in mathematics and spelling).[50,51] Furthermore, preterm infants' developmental challenges seem to compound over time; studies suggest that their performance in language-processing tasks gets worse over time in comparison to age-matched peers.[52] Hence, it is paramount to ameliorate the difficulties arising later in life as early as possible.

The atypical neurophysiology of the preterm infant is apparent in gray and white matter abnormalities in several brain regions that are associated with cognitive impairment later in development.[53] In terms of functional neurodevelopment, preterm infants elicit abnormal auditory brain responses in comparison with normally developing infants, associated with adverse neurocognitive outcomes in both infancy[54] and childhood.[51] Thus, musical interventions influencing basic auditory processing from early age could potentially improve preterm infants' language outcomes. In particular, vocal music exposure, especially when sung by a parent, has been suggested to have therapeutic effects on the developing hearing in preterm infants.[63] Unfortunately, long-term effects of musical interventions on preterm infant development have not been extensively investigated thus far.

Musical interventions for preterm infants, if effective, may have many benefits. For example, a recent randomized clinical trial showed that music therapy consisting of exposing the infant to live elements of music, such as applied womb, heart, and breath sounds and parent-preferred lullabies, lowered heart rates and promoted sleep, sucking behavior, and caloric intake of preterm infants in neonatal intensive care units.[57] Intervention effects may also extend beyond the infant. Premature birth is a risk for the child's development, but it is also a traumatic event for the parents. Thus, musical interventions should benefit both the infant's development and the parents' well-being. Another relevant aspect for interventions aimed at preterm infants comes from work that emphasized using live (as opposed to recorded) sounds in preterm infant music interventions.[57] One approach to use live sounds that could benefit both parents and infants could be to incorporate elements of music therapy into kangaroo care—skin-to-skin contact between the parent and the preterm infant. Kangaroo care has been shown to be very beneficial for early development of the preterm infant and to reduce parental anxiety.[64] Combining parental singing of music of their own choosing with kangaroo care provides a convenient way to introduce

music into parent–infant interaction. Such an intervention could potentially have long-term effects, as parental singing can improve maternal sensitivity,[4] which is positively associated with language development in preterm children.[65]

Singing Kangaroo: preliminary results

The Finnish–Swedish Singing Kangaroo trial investigates whether parental singing affects neural responses associated with speech–sound discrimination and improves bonding between parents and the child early in life in children born very preterm, as well as whether this has long-term effects on infant cognition. In the study, preterm infants are randomized to either standard kangaroo care or a singing group. In the singing group, parents are inspired and supported to sing or hum songs and melodies of their own choosing in a manner most natural to the parents themselves during kangaroo care administration. Specifically, the aim of the intervention is to empower parents to sing more with their infants throughout childhood. Thus, the intervention aims to improve not only the auditory discrimination abilities of the infants, but also the attachment between the child and the caregiver(s), hopefully leading to improved social growth, academic performance, and well-being for the children.

At term, the preterm infants undergo an auditory ERP recording with EEG or magnetoencephalography using a similar paradigm with native language speech sound changes as in the DyslexiaBaby study, and at 2–2.5 years of age their development is assessed using a comprehensive neuropsychological test battery of language and cognitive functions (e.g., Bayley Scales of Infant Development,[66] MacArthur–Bates Communicative Development Inventories[67]). Additionally, broad questionnaires on parental background as in the DyslexiaBaby study are administered to the parents in the Singing Kangaroo study to control for effects of family background, as reviewed above. The aim is to study the same associations between infant auditory ERPs, early language skills, and music activities at home in the DyslexiaBaby and Singing Kangaroo studies. This enables validation of effects in two independent samples.

Preliminary results ($n = 23$, final sample $n = 60$; Swedish cohort) from the Singing Kangaroo study imply that, at term, preterm infants participating in the singing group show neural responses to language more akin to those of the healthy full-term children. However, preterm infants' neural responses in the standard care group differ from those of full-term controls, in line with previous studies.[55] Whether these group differences predict long-term positive effects is still unknown. In the Swedish cohort, the singing intervention seems to particularly empower fathers to spend more time singing and in skin-to-skin contact with the preterm infant. Increased amount of kangaroo care and parental singing can positively affect parental sensitivity and thus also language outcomes.[65] Furthermore, early reports from the Finnish cohort ($n = 27$, final sample $n = 45$) of the Singing Kangaroo study suggest that musical activities at home are positively associated with language outcomes in toddlers, as also preliminarily seen in 6-month-olds in the DyslexiaBaby study.

It is notable that music therapy in general, as well as previously reported music interventions, including the DyslexiaBaby and Singing Kangaroo interventions, are likely to influence the participating families in several ways. For example, songs and melodies from the interventions will become very familiar to parents and other family members, which may make it more likely that the parents or siblings of the infant sing at home. Participating in the interventions per se may also highlight the possible beneficial effects of music to the parents, and thus increase the likelihood that they engage their children in musical activities. These possible consequences of the intervention could result in more social, active, and long-lasting music exposure for the infant than the intervention itself. The longitudinal settings enable follow-up of these processes in the families, hopefully providing a comprehensive view of early neurocognitive development and the role of music in it.

Conclusions and future directions

Together with previous findings, preliminary results from the DyslexiaBaby and Singing Kangaroo studies highlight the role of music in promoting early development, at least when music making is active and social. Musical activities and singing influence early language skills in infants and toddlers, as well as auditory cortical processing of speech sounds. Correlations between the auditory ERPs and precommunicative development scores in infancy offer the promise of ERPs as early neural markers of language difficulties and support the suggested link

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between auditory and language skills.[5] Furthermore, the results indicate that activities at home, such as music, can be valuable in supporting infant and child development, even in at-risk groups. Having professionals guide the parents to engage in these activities could be a cost-effective way to ameliorate adverse outcomes in at-risk children.

According to current research, it may well be that, like language learning, learning from music in infancy benefits largely from social interaction.[27] The differential effects of very early music interventions may then not arise from whether the intervention is active versus passive, but rather whether the intervention is social and whether it promotes widespread adoption of music into daily life and parenting. Specifically, the music intervention is likely to have a lasting effect if the parents can select the music and use music in parenting in a way best suited for them. Thus, empowering parents to include music in parent–infant interactions may be the most fruitful approach in infant interventions, as it can support attachment and allow motivated parents to direct the infant's attention to music on a regular basis. Furthermore, as infants have been suggested to be highly multimodal learners,[68,69] it may be that it is the multimodality of interactive and social music making (e.g., compared with music listening) that is essential for early learning and intervention efficacy. Future studies assessing the effects of music interventions should strive to disentangle the effects arising from active practice of musical skills, multimodal versus unimodal aspects of learning, and the benefits of social interaction on development.

Taken together, very early music interventions and incorporating music into daily life may be beneficial for auditory and language development in at-risk infants. A task for future research is to search for the most effective administration and dosage for these interventions, so that as many children as possible could avoid negative developmental cascades—and become familiar with the social and aesthetic benefits of music.

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Competing interests

The authors declare no competing interests.

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